MRI-Based Computational Fluid Dynamics in Arterial Models: A Quantitative Evaluation

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Previous studies have investigated the ability of computational fluid dynamics (CFD) to simulate blood flow through, usually, qualitative comparisons between CFD and experimental results. The objective of this study was to quantitatively investigate the reliability of magnetic resonance (MR) image-based CFD simulations. An aortic and a carotid glass models were scanned in a 1.5T MR scanner. Axial- and oblique-slice MR acquisitions provided the images for the geometric reconstruction of both models. The vessel lumens were segmented using a snake algorithm and the extracted wall data was used to construct the models using a NURBS modeling software. The geometry was then imported into a CFD software package. The preprocessor of the package created the mesh and the finite-volume numerical solver performed the simulation. Three-directional MR velocity measurements, for flow rates 0.9-3.0 L/min, provided the true inlet boundary conditions as well as the necessary three-directional velocity data to validate the computational models. The MR velocity vector plots revealed features identical to those in the image–based CFD velocity vector plots. The average velocity differences between MR and CFD was less than 2.0 cm/s in the aortic model and less than 2.5 cm/s in the carotid model. The local velocity differences between MR and CFD were less than 2.5 cm/s in more than 75% and 60% of the total flow field in the aortic and carotid models, respectively. The results support the hypothesis that image-based CFD simulations can reliably predict the velocity field in arterial models.